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**Amendments to the Claims:**

This listing of claims will replace all prior versions, and listings, of claims in the application:

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**Listing of Claims:**

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1. (Cancelled)

2. (Cancelled)

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3. (Currently Amended) ~~An apparatus for blind separation of an overcomplete set of mixed signals as set forth in claim 2,~~ An apparatus for blind separation of an overcomplete set of mixed signals, the apparatus comprising:

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i. a data processing system including an input for receiving mixed signals from a plurality of sensors configured to receive mixed signal samples comprising a mixture of signals transmitted from signal sources through an environment and noise, a signal processor attached with the input for receiving the mixed signals from the sensors, and a memory for storing data during operations of the signal processor; the data processing system further comprising:

30

ii. means for storing data representing the input from the sensors in a mixed signal matrix  $\mathbf{X}$ ;

iii. means for storing data representing the noise in a noise matrix  $\mathbf{V}$ ;

iv. means for storing data representing an estimate of the individual signals from the mixture of signals from the signal sources in a source signal estimate matrix  $\hat{\mathbf{S}}$ ;

- 5           v. means for storing data representing an estimate of the effects of the environment in a estimated mixing matrix  $\hat{A}$  where the matrices are related by  $X = \hat{A}\hat{S} + V$ ;
- vi. means for generating an initial estimate of the estimated mixing matrix  $\hat{A}$ ;
- vii. means for determining the number of signal sources and associated lines of  
10           correlation of each of the signal sources from the estimated mixing matrix  $\hat{A}$ , and for representing the signal sources in the source signal estimate matrix  $\hat{S}$ ;
- viii. means for jointly optimizing the source signal estimate matrix  $\hat{S}$  and the estimated mixing matrix  $\hat{A}$  in an iterative manner, to generate an optimized  
15           source signal estimate matrix  $\hat{S}$  and a final estimated mixing matrix  $\hat{A}$ ; and
- ix. means for restoring the separated source signals from the optimized source signal estimate matrix  $\hat{S}$ , whereby a plurality of mixed signals from unknown sources traveling through an environment with added noise may be separated so that the original, separate signals may be reconstructed,  
20           wherein the means for generating an initial estimate of the estimated mixing matrix  $\hat{A}$  comprises:
- i. means for transforming the mixed signal matrix  $X$  into the sparse domain using a transform operator;
- ii. means for determining a frequency band within the sparse domain that  
25           contains the most information that can be used to determine lines of correlation to determine the number of signal sources;
- iii. means for determining a measure and an optimal threshold for the measure for the determination of noise within the frequency band;
- iv. means for recalculating the measure used in the determination of the noise within the frequency band using the optimal threshold; and  
30           means for determining the local maxima of a distribution of the measure, where the local maxima represent angles which are inserted

5                    into the estimated mixing matrix  $\hat{A}$  to provide an initial estimate of  
                      the estimated mixing matrix  $\hat{A}$ ;

                      wherein the means for jointly optimizing the source signal estimate matrix  $\hat{S}$  and  
                      the estimated mixing matrix  $\hat{A}$  in an iterative manner, to generate an optimized  
                      source signal estimate matrix  $\hat{S}$  and a final estimated mixing matrix  $\hat{A}$   
10                   comprises:

- i. means for clustering the mixed signal samples using a geometric  
                      constraint; and
- ii. means for evaluating a convergence criteria based on the clustered  
                      mixed signal samples to determine whether the convergence criteria  
15                   are met, and if the convergence criteria are not met, iteratively  
                      adjusting the clustering of the mixed signal samples and parameters of  
                      the geometric constraint to create a new set of clusters until the  
                      convergence criteria are met, to provide a final estimated mixing  
                      matrix  $\hat{A}$ .

20                   4. (Cancelled)

5. (Currently Amended) ~~An apparatus for blind separation of an overcomplete set of~~  
                      ~~mixed signals as set forth in claim 2~~ An apparatus for blind separation of an  
25                   overcomplete set of mixed signals, the apparatus comprising:

- i. a data processing system including an input for receiving mixed signals  
                      from a plurality of sensors configured to receive mixed signal samples  
                      comprising a mixture of signals transmitted from signal sources through an  
                      environment and noise, a signal processor attached with the input for  
30                   receiving the mixed signals from the sensors, and a memory for storing data  
                      during operations of the signal processor; the data processing system further  
                      comprising:

- 5           ii. means for storing data representing the input from the sensors in a mixed signal matrix  $\mathbf{X}$ ;
- iii. means for storing data representing the noise in a noise matrix  $\mathbf{V}$ ;
- iv. means for storing data representing an estimate of the individual signals from the mixture of signals from the signal sources in a source signal
- 10           estimate matrix  $\hat{\mathbf{S}}$ ;
- v. means for storing data representing an estimate of the effects of the environment in a estimated mixing matrix  $\hat{\mathbf{A}}$  where the matrices are related by  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ;
- vi. means for generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ ;
- 15           vii. means for determining the number of signal sources and associated lines of correlation of each of the signal sources from the estimated mixing matrix  $\hat{\mathbf{A}}$ , and for representing the signal sources in the source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- viii. means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the
- 20           estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$ ; and
- ix. means for restoring the separated source signals from the optimized source signal estimate matrix  $\hat{\mathbf{S}}$ , whereby a plurality of mixed signals from unknown sources traveling through an environment with added noise may
- 25           be separated so that the original, separate signals may be reconstructed;
- wherein the means for generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:
- i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the sparse domain using a transform operator;
- 30           ii. means for determining a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;

- 5           iii. means for determining a measure and an optimal threshold for the measure  
              for the determination of noise within the frequency band;
- iv. means for recalculating the measure used in the determination of the noise  
                  within the frequency band using the optimal threshold; and
- v. means for determining the local maxima of a distribution of the measure,  
10            where the local maxima represent angles which are inserted into the  
              estimated mixing matrix  $\hat{\mathbf{A}}$  to provide an initial estimate of the estimated  
              mixing matrix  $\hat{\mathbf{A}}$ ;

              wherein the means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$   
              and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an  
15           optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$   
              further comprises:

- i.   means for obtaining a multi-band sparse domain estimate of the source  
                  signal estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ; and
- ii.   means for using the adjusted geometric constraint corresponding to the  
20           final estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the sparse  
              domain for the source signal estimate matrix  $\hat{\mathbf{S}}$  and determining whether  
              a convergence criteria is met for the source signal estimate matrix  $\hat{\mathbf{S}}$ ,  
              and if the convergence criteria are not met, iteratively adjusting the  
              clustering of the mixed signal samples to create a new set of clusters  
25           until the convergence criteria are met, to provide a final source signal  
              estimate matrix  $\hat{\mathbf{S}}$ .

6. (Cancelled)

- 30   7. (Currently Amended) An apparatus for blind separation of an overcomplete set of  
          mixed signals as set forth in claim 3 +, wherein the means for generating an initial  
          estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:

- 5           i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the frequency domain using a Fourier operator;
- ii. means for using a mutual information criterion to determine a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;
- 10           iii. means for determining a random variable  $ang = \arctan \frac{x_i(band)}{x_j(band)}$ , where  $x_i(band)$  and  $x_j(band)$  represent Fourier values of mixture in the selected frequency band, and an optimal threshold ANG for  $ang$ , where the optimal threshold ANG is determined by computing the entropy  $E(ang, ANG)$  vs. ANG and searching for the optimal value of ANG corresponding to the
- 15           minimum rate of descent of the entropy  $E(ang, ANG)$ ;
- iv. means for recalculating  $ang$  based on the optimal threshold ANG;
- v. means for using a standard peak detection technique to determine the number and values of local maxima of a histogram of  $ang$  where the local maxima represent angles which are inserted into the estimated mixing matrix  $\hat{\mathbf{A}}$  to
- 20           provide an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ .
8. (Original) An apparatus for blind separation of an overcomplete set of mixed signals as set forth in claim 7, wherein the means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to
- 25           generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:
- i. means for clustering the mixed signal samples in the Fourier domain along the lines of correlation with one cluster per source using a straight distance metric geometric constraint, with the clusters representing estimates of the Fourier
- 30           domain representation of  $\hat{\mathbf{S}}$ ,  $\mathbf{F}(\hat{\mathbf{S}})$ , where  $\mathbf{F}$  represents a Fourier domain operator ; and

5           ii. means for evaluating a convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , with the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , developed from the log likelihood function  
 $\mathbf{L}(\mathbf{F}(\hat{\mathbf{S}}) | \mathbf{F}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source signals in the  
Fourier domain following the probability  $\mathbf{P}(\mathbf{F}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|}$ , where  
 $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ ,  
10           evaluated based on the clustered mixed signal samples to determine whether the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, and if the convergence criteria,  $\min$   
 $\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is not met, iteratively adjusting the clustering of the mixed signal  
samples and parameters of the geometric constraint to create a new set of  
clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, to provide a final  
15           estimated mixing matrix  $\hat{\mathbf{A}}$ .

9. (Original) An apparatus for blind separation of an overcomplete set of mixed signals  
as set forth in claim 8, wherein the means for jointly optimizing the source signal  
estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to  
20           generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing  
matrix  $\hat{\mathbf{A}}$  further comprises:

i. means for obtaining a multi-band sparse domain estimate of the source signal  
estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ , applied in the Wavelet  
domain; and  
25           ii. means for using the adjusted geometric constraint corresponding to the final  
estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the Wavelet domain for the  
source signal estimate matrix  $\hat{\mathbf{S}}$ ,  $\mathbf{W}(\hat{\mathbf{S}})$ , and determining whether a  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$  is met for the source signal estimate

5           matrix  $\hat{S}$ , where the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{S})|$ , is developed from  
the log likelihood function  $L(\mathbf{W}(\hat{S}) | \mathbf{W}(\mathbf{X}), \mathbf{A})$  with the assumption of  
Laplancity of source signals in the Wavelet domain following the probability  
 $P(\mathbf{W}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{W}(\hat{S})|}$ , where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, and if the  
convergence criteria is not met,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{S})|$ , iteratively adjusting the  
10          clustering of the mixed signal samples to create a new set of clusters until the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{S})|$ , is met, to provide a final source signal  
estimate matrix  $\hat{S}$ .

10. (Original) An apparatus for blind separation of an overcomplete set of mixed signals  
15          as set forth in claim 9, wherein the apparatus is configured for separating mixed  
acoustic signals.

11. (Original) An apparatus for blind separation of an overcomplete set of mixed signals  
as set forth in claim 9, wherein the apparatus is configured for separating mixed radio  
20          frequency signals.

12. (Cancelled)

13. (Cancelled)

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14. (Currently Amended) ~~A method for blind separation of an overcomplete set of mixed  
signals as set forth in claim 13~~ A method for blind separation of an overcomplete set  
of mixed signals, using a data processing system including an input for receiving  
mixed signals from a plurality of sensors configured to receive mixed signal samples  
30          comprising a mixture of signals transmitted from signal sources through an  
environment and noise, a signal processor attached with the input for receiving the



5        mixed signals from the sensors, and a memory for storing data during operations of the signal processor the method comprising the steps of:

        i. storing data representing the input from the sensors in a mixed signal matrix  $\underline{X}$ ;

        ii. storing data representing the noise in a noise matrix  $\underline{V}$ ;

10        iii. storing data representing an estimate of the individual signals from the mixture of signals from the signal sources in a source signal estimate matrix  $\underline{\hat{S}}$ ;

        iv. storing data representing an estimate of the effects of the environment in a estimated mixing matrix  $\underline{\hat{A}}$  where the matrices are related by  $\underline{X} = \underline{\hat{A}}\underline{\hat{S}} + \underline{V}$ ;

15        v. generating an initial estimate of the estimated mixing matrix  $\underline{\hat{A}}$ ;

        vi. determining the number of signal sources and associated lines of correlation of each of the signal sources from the estimated mixing matrix  $\underline{\hat{A}}$ , and for representing the signal sources in the source signal estimate matrix  $\underline{\hat{S}}$ ;

        vii. jointly optimizing the source signal estimate matrix  $\underline{\hat{S}}$  and the estimated mixing matrix  $\underline{\hat{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\underline{\hat{S}}$  and a final estimated mixing matrix  $\underline{\hat{A}}$ ; and

        viii. restoring the separated source signals from the optimized source signal estimate matrix  $\underline{\hat{S}}$ , whereby a plurality of mixed signals from unknown sources traveling through an environment with added noise may be

25        separated so that the original, separate signals may be reconstructed;

wherein the step of generating an initial estimate of the estimated mixing matrix  $\underline{\hat{A}}$  comprises the sub-steps of:

        i. transforming the mixed signal matrix  $\underline{X}$  into the sparse domain using a transform operator;

30        ii. determining a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;

- 5           iii. determining a measure and an optimal threshold for the measure for the  
              determination of noise within the frequency band;  
              iv. recalculating the measure used in the determination of the noise within the  
                  frequency band using the optimal threshold; and  
              v. determining the local maxima of a distribution of the measure, where the  
10           local maxima represent angles which are inserted into the estimated mixing  
              matrix  $\hat{A}$  to provide an initial estimate of the estimated mixing matrix  $\hat{A}$  ,  
              and

              wherein the step of jointly optimizing the source signal estimate matrix  $\hat{S}$  and the  
              estimated mixing matrix  $\hat{A}$  in an iterative manner, to generate an optimized source  
15           signal estimate matrix  $\hat{S}$  and a final estimated mixing matrix  $\hat{A}$  comprises the sub-  
              steps of:

- i. clustering the mixed signal samples using a geometric constraint; and  
              ii. evaluating a convergence criteria based on the clustered mixed signal  
                  samples to determine whether the convergence criteria are met, and if  
20           the convergence criteria are not met, iteratively adjusting the clustering  
              of the mixed signal samples and parameters of the geometric constraint  
              to create a new set of clusters until the convergence criteria are met, to  
              provide a final estimated mixing matrix  $\hat{A}$  .

25   15. (Cancelled)

16. (Currently Amended) ~~A method for blind separation of an overcomplete set of mixed~~  
              ~~signals as set forth in claim 13~~ A method for blind separation of an overcomplete set  
              of mixed signals, using a data processing system including an input for receiving  
30           mixed signals from a plurality of sensors configured to receive mixed signal samples  
              comprising a mixture of signals transmitted from signal sources through an  
              environment and noise, a signal processor attached with the input for receiving the  
              mixed signals from the sensors, and a memory for storing data during operations of  
              the signal processor the method comprising the steps of:

- 5           i. storing data representing the input from the sensors in a mixed signal matrix  $\mathbf{X}$ ;
- ii. storing data representing the noise in a noise matrix  $\mathbf{V}$ ;
- iii. storing data representing an estimate of the individual signals from the mixture of signals from the signal sources in a source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- 10           iv. storing data representing an estimate of the effects of the environment in a estimated mixing matrix  $\hat{\mathbf{A}}$  where the matrices are related by  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ;
- v. generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ ;
- vi. determining the number of signal sources and associated lines of correlation of each of the signal sources from the estimated mixing matrix  $\hat{\mathbf{A}}$ , and for representing the signal sources in the source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- 15           vii. jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$ ; and
- 20           viii. restoring the separated source signals from the optimized source signal estimate matrix  $\hat{\mathbf{S}}$ , whereby a plurality of mixed signals from unknown sources traveling through an environment with added noise may be separated so that the original, separate signals may be reconstructed;
- wherein the step of generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises the sub-steps of:
- 25           i. transforming the mixed signal matrix  $\mathbf{X}$  into the sparse domain using a transform operator;
- ii. determining a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;
- 30           iii. determining a measure and an optimal threshold for the measure for the determination of noise within the frequency band;

- 5           iv. recalculating the measure used in the determination of the noise within the  
              frequency band using the optimal threshold; and  
              v. determining the local maxima of a distribution of the measure, where the  
                  local maxima represent angles which are inserted into the estimated  
                  mixing matrix  $\hat{\mathbf{A}}$  to provide an initial estimate of the estimated mixing  
10           matrix  $\hat{\mathbf{A}}$ , and

wherein the wherein the step of jointly optimizing the source signal estimate  
matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to  
generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated  
mixing matrix  $\hat{\mathbf{A}}$  further comprises the sub steps of:

- 15           i. obtaining a multi-band sparse domain estimate of the source signal  
              estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ; and  
              ii. using the adjusted geometric constraint corresponding to the final  
                  estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the sparse domain  
                  for the source signal estimate matrix  $\hat{\mathbf{S}}$  and determining whether a  
20           convergence criteria is met for the source signal estimate matrix  $\hat{\mathbf{S}}$ , and  
              if the convergence criteria are not met, iteratively adjusting the  
              clustering of the mixed signal samples to create a new set of clusters  
              until the convergence criteria are met, to provide a final source signal  
              estimate matrix  $\hat{\mathbf{S}}$ .

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17. (Cancelled)

18. (Currently Amended) A method for blind separation of an overcomplete set of mixed  
signals as set forth in claim 14 12, wherein the step of generating an initial estimate of  
30           the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises the sub steps of:  
              i. transforming the mixed signal matrix  $\mathbf{X}$  into the frequency domain using a  
                  Fourier operator;

- 5           ii. using a mutual information criterion to determine a frequency band within the  
              sparse domain that contains the most information that can be used to  
              determine lines of correlation to determine the number of signal sources;
  - iii. determining a random variable  $ang = \arctan \frac{x_i(band)}{x_j(band)}$ , where  $x_i(band)$  and  
               $x_j(band)$  represent Fourier values of mixture in the selected frequency band,  
10           and an optimal threshold ANG for  $ang$ , where the optimal threshold ANG is  
              determined by computing the entropy  $E(ang, ANG)$  vs. ANG and searching  
              for the optimal value of ANG corresponding to the minimum rate of descent  
              of the entropy  $E(ang, ANG)$ ;
  - iv. recalculating  $ang$  based on the optimal threshold ANG;
  - 15           v. using a standard peak detection technique to determine the number and values  
              of local maxima of a histogram of  $ang$  where the local maxima represent  
              angles which are inserted into the estimated mixing matrix  $\hat{A}$  to provide an  
              initial estimate of the estimated mixing matrix  $\hat{A}$ .
- 20   19. (Original) A method for blind separation of an overcomplete set of mixed signals as  
set forth in claim 18, wherein the step of jointly optimizing the source signal estimate  
matrix  $\hat{S}$  and the estimated mixing matrix  $\hat{A}$  in an iterative manner, to generate an  
optimized source signal estimate matrix  $\hat{S}$  and a final estimated mixing matrix  $\hat{A}$   
comprises the sub steps of:
- 25           i. clustering the mixed signal samples in the Fourier domain along the lines of  
              correlation with one cluster per source using a straight distance metric  
              geometric constraint, with the clusters representing estimates of the Fourier  
              domain representation of  $\hat{S}$ ,  $F(\hat{S})$ , where  $F$  represents a Fourier domain  
              operator ; and
  - 30           ii. evaluating a convergence criteria,  $\min \lambda c^T |F(\hat{S})|$ , with the convergence criteria,  
               $\min \lambda c^T |F(\hat{S})|$ , developed from the log likelihood function  $L(F(\hat{S}) | F(X), A)$   
              with the assumption of Laplanicity of source signals in the Fourier domain

5 following the probability  $P(\mathbf{F}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|}$ , where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit  
vector, with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , evaluated based on the  
clustered mixed signal samples to determine whether the convergence criteria,  
 $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, and if the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is not  
met, iteratively adjusting the clustering of the mixed signal samples and  
10 parameters of the geometric constraint to create a new set of clusters until the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, to provide a final estimated mixing  
matrix  $\hat{\mathbf{A}}$ .

20. (Original) A method for blind separation of an overcomplete set of mixed signals as  
15 set forth in claim 19, wherein the wherein the step of jointly optimizing the source  
signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner,  
to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated  
mixing matrix  $\hat{\mathbf{A}}$  further comprises the sub steps of:

- i. obtaining a multi-band sparse domain estimate of the source signal estimate  
20 matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ , applied in the Wavelet domain;  
and
- ii. using the adjusted geometric constraint corresponding to the final estimated  
mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the Wavelet domain for the source  
signal estimate matrix  $\hat{\mathbf{S}}$ ,  $\mathbf{W}(\hat{\mathbf{S}})$ , and determining whether a convergence  
25 criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$  is met for the source signal estimate matrix  $\hat{\mathbf{S}}$ , where  
the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is developed from the log likelihood  
function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source  
signals in the Wavelet domain following the probability  $P(\mathbf{W}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|}$ ,  
where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, and if the convergence criteria is not met,

5            $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , iteratively adjusting the clustering of the mixed signal samples  
to create a new set of clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is  
met, to provide a final source signal estimate matrix  $\hat{\mathbf{S}}$ .

21. (Original) A method for blind separation of an overcomplete set of mixed signals as  
10       set forth in claim 20, wherein the method is configured to separate mixed acoustic  
signals.

22. (Original) A method for blind separation of an overcomplete set of mixed signals as  
set forth in claim 20, wherein the method is configured to separate mixed radio  
15       frequency signals.

23. (Cancelled)

24. (Cancelled)

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25. (Currently Amended) ~~A computer program product for blind separation of an  
overcomplete set of mixed signals as set forth in claim 24~~ A computer program  
product for blind separation of an overcomplete set of mixed signals, readable on a  
data processing system including an input for receiving mixed signals from a plurality  
25       of sensors configured to receive mixed signal samples comprising a mixture of  
signals transmitted from signal sources through an environment and noise, a signal  
processor attached with the input for receiving the mixed signals from the sensors,  
and a memory for storing data during operations of the signal processor the computer  
program product comprising means, stored on a computer readable medium, for:

- 30           i. storing data representing the input from the sensors in a mixed signal matrix  
 $\mathbf{X}$ ;  
ii. storing data representing the noise in a noise matrix  $\mathbf{V}$ ;

- 5            iii. storing data representing an estimate of the individual signals from the mixture of signals from the signal sources in a source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- iv. storing data representing an estimate of the effects of the environment in a estimated mixing matrix  $\hat{\mathbf{A}}$  where the matrices are related by  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ;
- 10          v. generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ ;
- vi. determining the number of signal sources and associated lines of correlation of each of the signal sources from the estimated mixing matrix  $\hat{\mathbf{A}}$ , and for representing the signal sources in the source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- vii. jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated
- 15           mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$ ; and
- viii. restoring the separated source signals from the optimized source signal estimate matrix  $\hat{\mathbf{S}}$ , whereby a plurality of mixed signals from unknown
- sources traveling through an environment with added noise may be
- 20           separated so that the original, separate signals may be reconstructed,
- wherein the means for generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:
- i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the sparse domain using a transform operator;
- 25           ii. means for determining a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;
- iii. means for determining a measure and an optimal threshold for the measure for the determination of noise within the frequency band;
- 30           iv. means for recalculating the measure used in the determination of the noise within the frequency band using the optimal threshold; and



5. v. means for determining the local maxima of a distribution of the measure,  
where the local maxima represent angles which are inserted into the  
estimated mixing matrix  $\hat{A}$  to provide an initial estimate of the estimated  
mixing matrix  $\hat{A}$ , and

wherein the means for jointly optimizing the source signal estimate matrix  $\hat{S}$  and the  
10 estimated mixing matrix  $\hat{A}$  in an iterative manner, to generate an optimized source  
signal estimate matrix  $\hat{S}$  and a final estimated mixing matrix  $\hat{A}$  comprises:

- i. means for clustering the mixed signal samples using a geometric constraint; and
- ii. means for evaluating a convergence criteria based on the clustered mixed signal  
15 samples to determine whether the convergence criteria are met, and if the  
convergence criteria are not met, iteratively adjusting the clustering of the  
mixed signal samples and parameters of the geometric constraint to create a new  
set of clusters until the convergence criteria are met, to provide a final estimated  
mixing matrix  $\hat{A}$ .

20 26. (Cancelled)

27. (Currently Amended) ~~A computer program product for blind separation of an~~  
~~overcomplete set of mixed signals as set forth in claim 24, A computer program~~  
25 product for blind separation of an overcomplete set of mixed signals, readable on a  
data processing system including an input for receiving mixed signals from a plurality  
of sensors configured to receive mixed signal samples comprising a mixture of  
signals transmitted from signal sources through an environment and noise, a signal  
processor attached with the input for receiving the mixed signals from the sensors,  
and a memory for storing data during operations of the signal processor the computer  
30 program product comprising means, stored on a computer readable medium, for:

- i. storing data representing the input from the sensors in a mixed signal matrix  
 $X$ ;
- ii. storing data representing the noise in a noise matrix  $V$ ;

- 5           iii. storing data representing an estimate of the individual signals from the mixture of signals from the signal sources in a source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- iv. storing data representing an estimate of the effects of the environment in a estimated mixing matrix  $\hat{\mathbf{A}}$  where the matrices are related by  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ;
- 10          v. generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ ;
- vi. determining the number of signal sources and associated lines of correlation of each of the signal sources from the estimated mixing matrix  $\hat{\mathbf{A}}$ , and for representing the signal sources in the source signal estimate matrix  $\hat{\mathbf{S}}$ ;
- vii. jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$ ; and
- 15          viii. restoring the separated source signals from the optimized source signal estimate matrix  $\hat{\mathbf{S}}$ , whereby a plurality of mixed signals from unknown sources traveling through an environment with added noise may be
- 20          separated so that the original, separate signals may be reconstructed,  
wherein the means for generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:
- i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the sparse domain using a transform operator;
- 25          ii. means for determining a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;
- iii. means for determining a measure and an optimal threshold for the measure for the determination of noise within the frequency band;
- 30          iv. means for recalculating the measure used in the determination of the noise within the frequency band using the optimal threshold; and

- 5                    v. means for determining the local maxima of a distribution of the  
measure, where the local maxima represent angles which are inserted  
into the estimated mixing matrix  $\hat{\mathbf{A}}$  to provide an initial estimate of  
the estimated mixing matrix  $\hat{\mathbf{A}}$ , and

wherein the wherein the means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$   
10 and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized  
source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$  further  
comprises:

- i. means for obtaining a multi-band sparse domain estimate of the source signal  
estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ ; and  
15 ii. means for using the adjusted geometric constraint corresponding to the final  
estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the sparse domain for the  
source signal estimate matrix  $\hat{\mathbf{S}}$  and determining whether a convergence criteria  
is met for the source signal estimate matrix  $\hat{\mathbf{S}}$ , and if the convergence criteria  
are not met, iteratively adjusting the clustering of the mixed signal samples to  
20 create a new set of clusters until the convergence criteria are met, to provide a  
final source signal estimate matrix  $\hat{\mathbf{S}}$ .

28. (Cancelled)

- 25 29. (Currently Amended) A computer program product for blind separation of an  
overcomplete set of mixed signals as set forth in claim 25 23, wherein the means for  
generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:  
i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the frequency domain  
using a Fourier operator;  
30 ii. means for using a mutual information criterion to determine a frequency band  
within the sparse domain that contains the most information that can be used  
to determine lines of correlation to determine the number of signal sources;

- 5           iii. means for determining a random variable  $ang = \arctan \frac{x_i(band)}{x_j(band)}$ , where
- $x_i(band)$  and  $x_j(band)$  represent Fourier values of mixture in the selected frequency band, and an optimal threshold ANG for  $ang$ , where the optimal threshold ANG is determined by computing the entropy  $E(ang, ANG)$  vs. ANG and searching for the optimal value of ANG corresponding to the
- 10           minimum rate of descent of the entropy  $E(ang, ANG)$ ;
- iv. means for recalculating  $ang$  based on the optimal threshold ANG;
- v. means for using a standard peak detection technique to determine the number and values of local maxima of a histogram of  $ang$  where the local maxima represent angles which are inserted into the estimated mixing matrix  $\hat{\mathbf{A}}$  to
- 15           provide an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ .
30. (Original) A computer program product for blind separation of an overcomplete set of mixed signals as set forth in claim 29, wherein the means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative
- 20           manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:
- i. means for clustering the mixed signal samples in the Fourier domain along the lines of correlation with one cluster per source using a straight distance metric geometric constraint, with the clusters representing estimates of the Fourier
- 25           domain representation of  $\hat{\mathbf{S}}$ ,  $\mathbf{F}(\hat{\mathbf{S}})$ , where  $\mathbf{F}$  represents a Fourier domain operator ; and
- ii. means for evaluating a convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , developed from the log likelihood function  $\mathbf{L}(\mathbf{F}(\hat{\mathbf{S}}) | \mathbf{F}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source signals in the
- 30           Fourier domain following the probability  $\mathbf{P}(\mathbf{F}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|}$ , where

5             $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ ,  
evaluated based on the clustered mixed signal samples to determine whether the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, and if the convergence criteria,  $\min$   
 $\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is not met, iteratively adjusting the clustering of the mixed signal  
samples and parameters of the geometric constraint to create a new set of  
10           clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, to provide a final  
estimated mixing matrix  $\hat{\mathbf{A}}$ .

31. (Original) A computer program product for blind separation of an overcomplete set of  
mixed signals as set forth in claim 30, wherein the wherein the means for jointly  
15           optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$   
in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and  
a final estimated mixing matrix  $\hat{\mathbf{A}}$  further comprises:

- i. means for obtaining a multi-band sparse domain estimate of the source signal  
estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ , applied in the Wavelet  
20           domain; and
- ii. means for using the adjusted geometric constraint corresponding to the final  
estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the Wavelet domain for the  
source signal estimate matrix  $\hat{\mathbf{S}}$ ,  $\mathbf{W}(\hat{\mathbf{S}})$ , and determining whether a  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$  is met for the source signal estimate  
25           matrix  $\hat{\mathbf{S}}$ , where the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is developed from  
the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A})$  with the assumption of  
Laplancity of source signals in the Wavelet domain following the probability  

$$P(\mathbf{W}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|}$$
, where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, and if the  
convergence criteria is not met,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , iteratively adjusting the

5           clustering of the mixed signal samples to create a new set of clusters until the  
convergence criteria,  $\min \lambda c^T |W(\hat{S})|$ , is met, to provide a final source signal  
estimate matrix  $\hat{S}$ .

10           32. (Original) A computer program product for blind separation of an overcomplete set of  
mixed signals as set forth in claim 30, wherein the computer program product is  
configured for separating mixed acoustic signals.

15           33. (Original) A computer program product for blind separation of an overcomplete set of  
mixed signals as set forth in claim 30, wherein the computer program product is  
configured for separating mixed radio frequency signals.

34. (Cancelled)

20           35. (Currently Amended) ~~An apparatus for determining a CR bound for an estimated  
mixing matrix  $\hat{A}$  developed in the blind separation of an overcomplete set of mixed  
signals as set forth in claim 34;~~ An apparatus for determining a CR bound for an  
estimated mixing matrix  $\hat{A}$  developed in the blind separation of an overcomplete set  
of mixed signals, the apparatus comprising a data processing system including a  
processor, a memory coupled with the processor, an input coupled with the processor,  
25           an output coupled with the processor, means within the data processing system for  
generating a CR bound for the estimated mixing matrix  $\hat{A}$ , and means for generating  
an output of the expected value for the estimation error of associated lines of  
correlation and for providing the output to a user via the output, whereby a CR bound  
may be developed for determining the performance of an estimate of a mixing matrix  
30            $\hat{A}$  developed in the blind separation of an overcomplete set of mixed signals in order  
that a user may know the performance limitations of a blind separation apparatus.

5 wherein the means for determining the expected value for the estimation error is in the form of  $E\{\theta_i - \hat{\theta}_i\}^2$  where  $E\{\theta_i - \hat{\theta}_i\}^2 \geq \frac{\lambda_k^2}{2Nu^T(\theta_i)\mathbf{p}^T\mathbf{R}_{w(v)}^{-1}\mathbf{p}u(\theta_i)}$ , where:

$E\{\theta_i - \hat{\theta}_i\}^2$  is an expected value for the estimation error of associated lines of correlation;

$\theta_i = \arctan\left(\frac{\mathbf{a}_i}{\|\mathbf{a}_i\|}\right)$ , where  $\mathbf{a}_i = \begin{bmatrix} a_{1i} \\ a_{2i} \end{bmatrix}$ ,  $i = 1, 2, \dots, M$ , and  $\hat{\mathbf{A}} = \hat{\mathbf{A}}(\theta) = \mathbf{u}(\theta_i)$ ;

10  $\hat{\theta}_i$  is an estimated value corresponding to an actual value of  $\theta_i$ ;

$\lambda_k^2$  is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A}(\theta))$  used for the estimation of the mixing matrix  $\hat{\mathbf{A}}$  and the estimation of a source signal estimate matrix  $\hat{\mathbf{S}}$ ;

$N$  is a number of data samples used in the generation of the mixing matrix

15  $\hat{\mathbf{A}}$  and the source signal estimate matrix  $\hat{\mathbf{S}}$ ;

$\mathbf{u}(\theta_i) = \begin{bmatrix} \cos(\theta_i) \\ \sin(\theta_i) \end{bmatrix}$ ;

$\mathbf{p} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$ ;

$T$  is the transpose operator; and

$\mathbf{R}_{w(v)}^{-1} = \begin{bmatrix} \sigma_{w(v)}^2 & \rho\sigma_{w(v)}^2 \\ \rho\sigma_{w(v)}^2 & \sigma_{w(v)}^2 \end{bmatrix}$ , where  $\sigma_{w(v)}^2$  is a cross correlation of a noise

20 set and  $\rho$  is a constant multiplier value.

36. (Cancelled).

37. (Currently Amended) ~~An apparatus for determining a CR bound for a source signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of mixed signals as set forth in claim 36, An apparatus for determining a CR bound for an~~  
25 source signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete

5 set of mixed signals, the apparatus comprising a data processing system including a  
processor, a memory coupled with the processor, an input coupled with the processor,  
an output coupled with the processor, means within the data processing system for  
generating a CR bound for the source signal estimate matrix  $\hat{\mathbf{S}}$ , and means for  
generating an output of the expected value for the estimation error of associated lines  
10 of correlation and for providing the output to a user via the output, whereby a CR  
bound may be developed for determining the performance of an estimate of a source  
signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of  
mixed signals in order that a user may know the performance limitations of a blind  
separation apparatus,

15 wherein the means for determining the expected value for the estimation error is in  
the form of  $E\{\mathbf{W}(\mathbf{S}) - \mathbf{W}(\hat{\mathbf{S}})\}^2$

where  $E\{\mathbf{W}(\mathbf{S}) - \mathbf{W}(\hat{\mathbf{S}})\}^2 \geq \left( \sigma_v^2 \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \hat{\mathbf{A}}^T(\theta) \hat{\mathbf{A}}(\theta) + \lambda^2 \mathbf{I} \right)^{-1}$ , where

$\sigma_v^2$  represents a noise level;

$\rho$  is a constant multiplier value;

20  $\hat{\mathbf{A}}$  is an estimated mixing matrix;

$\theta_i = \arctan\left(\frac{\mathbf{a}_i}{\|\mathbf{a}_i\|}\right)$ , where  $\mathbf{a}_i = \begin{bmatrix} a_{1i} \\ a_{2i} \end{bmatrix}$ ,  $i = 1, 2, \dots, M$ , and  $\hat{\mathbf{A}} = \hat{\mathbf{A}}(\theta) = \mathbf{u}(\theta_i)$ ;

$\lambda_k^2$  is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A}(\theta))$ ; and

$\mathbf{I}$  is an identity matrix.

25 38. (Cancelled)

39. (Currently Amended) A method for determining a CR bound for an estimated mixing  
matrix  $\hat{\mathbf{A}}$  developed in the blind separation of an overcomplete set of mixed signals as  
set forth in claim 38, A method for determining a CR bound for an estimated mixing  
30 matrix  $\hat{\mathbf{A}}$  developed in the blind separation of an overcomplete set of mixed signals,



5 operating on an apparatus comprising a data processing system including a processor,  
a memory coupled with the processor, an input coupled with the processor, an output  
coupled with the processor, the method comprising the steps of generating a CR  
bound for the estimated mixing matrix  $\hat{\mathbf{A}}$ , and generating an output of the expected  
value for the estimation error of associated lines of correlation and for providing the  
10 output to a user via the output, whereby a CR bound may be developed for  
determining the performance of an estimate of a mixing matrix  $\hat{\mathbf{A}}$  developed in the  
blind separation of an overcomplete set of mixed signals in order that a user may  
know the performance limitations of a blind separation apparatus,  
wherein in the step of determining the expected value for the estimation error, the  
15 expected value for estimation error is in the form of  $E\{\theta_i - \hat{\theta}_i\}^2$  where

$$E\{\theta_i - \hat{\theta}_i\}^2 \geq \frac{\lambda_k^2}{2N\mathbf{u}^T(\theta_i)\mathbf{p}^T\mathbf{R}_{w(v)}^{-1}\mathbf{p}\mathbf{u}(\theta_i)}, \text{ where:}$$

$E\{\theta_i - \hat{\theta}_i\}^2$  is an expected value for the estimation error of associated  
lines of correlation;

$$\theta_i = \arctan\left(\frac{\mathbf{a}_i}{\|\mathbf{a}_i\|}\right), \text{ where } \mathbf{a}_i = \begin{bmatrix} a_{1i} \\ a_{2i} \end{bmatrix}, i = 1, 2, \dots, M, \text{ and } \hat{\mathbf{A}} = \hat{\mathbf{A}}(\theta) = \mathbf{u}(\theta_i);$$

20  $\hat{\theta}_i$  is an estimated value corresponding to an actual value of  $\theta_i$ ;

$\lambda_k^2$  is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A}(\theta))$   
used for the estimation of the mixing matrix  $\hat{\mathbf{A}}$  and the estimation of a  
source signal estimate matrix  $\hat{\mathbf{S}}$ ;

$N$  is a number of data samples used in the generation of the mixing matrix  
25  $\hat{\mathbf{A}}$  and the source signal estimate matrix  $\hat{\mathbf{S}}$ ;

$$\mathbf{u}(\theta_i) = \begin{bmatrix} \cos(\theta_i) \\ \sin(\theta_i) \end{bmatrix};$$

$$\mathbf{p} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix};$$

5  $T$  is the transpose operator; and

$$\mathbf{R}_{w(v)}^{-1} = \begin{bmatrix} \sigma_{w(v)}^2 & \rho \sigma_{w(v)}^2 \\ \rho \sigma_{w(v)}^2 & \sigma_{w(v)}^2 \end{bmatrix}, \text{ where } \sigma_{w(v)}^2 \text{ is a cross correlation of a noise}$$

set and  $\rho$  is a constant multiplier value.

40. (Cancelled).

10

41. (Currently Amended) ~~A method of determining a CR bound for a source signal~~

~~estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of mixed signals as set forth in claim 40; A method for determining a CR bound for an source~~

~~signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of~~

15

~~mixed signals, operated in an apparatus comprising a data processing system~~

~~including a processor, a memory coupled with the processor, an input coupled with~~

~~the processor, an output coupled with the processor, the method comprising the steps~~

~~of generating a CR bound for the source signal estimate matrix  $\hat{\mathbf{S}}$ , and generating an~~

~~output of the expected value for the estimation error of associated lines of correlation~~

20

~~and for providing the output to a user via the output, whereby a CR bound may be~~

~~developed for determining the performance of an estimate of a source signal estimate~~

~~matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of mixed signals in~~

~~order that a user may know the performance limitations of a blind separation~~

~~apparatus,~~

25

wherein the in the step of determining the expected value for the estimation error, the

expected value for the estimation error is in the form of  $E\{\left(\mathbf{W}(\mathbf{S}) - \mathbf{W}(\hat{\mathbf{S}})\right)^2\}$

where  $E\{\left(\mathbf{W}(\mathbf{S}) - \mathbf{W}(\hat{\mathbf{S}})\right)^2\} \geq \left( \sigma_v^2 \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \hat{\mathbf{A}}^T(\theta) \hat{\mathbf{A}}(\theta) + \lambda^2 \mathbf{I} \right)^{-1}$ , where

$\sigma_v^2$  represents a noise level;

$\rho$  is a constant multiplier value;

30

$\hat{\mathbf{A}}$  is an estimated mixing matrix;

5  $\theta_i = \arctan\left(\frac{\mathbf{a}_i}{\|\mathbf{a}_i\|}\right)$ , where  $\mathbf{a}_i = \begin{bmatrix} a_{1i} \\ a_{2i} \end{bmatrix}$ ,  $i = 1, 2, \dots, M$ , and  $\hat{\mathbf{A}} = \hat{\mathbf{A}}(\theta) = \mathbf{u}(\theta_i)$ ;

$\lambda_k^2$  is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A}(\theta))$ ; and

$\mathbf{I}$  is an identity matrix.

42. (Cancelled).

10

43. (Currently Amended) ~~A computer program product for determining a CR bound for an estimated mixing matrix  $\hat{\mathbf{A}}$  developed in the blind separation of an overcomplete set of mixed signals as set forth in claim 42;~~ A computer program product for determining a CR bound for an estimated mixing matrix  $\hat{\mathbf{A}}$  developed in the blind separation of an overcomplete set of mixed signals, the computer program product being written onto a medium readable on a data processing system including a processor, a memory coupled with the processor, an input coupled with the processor, an output coupled with the processor, with the computer program product comprising means for generating a CR bound for the estimated mixing matrix  $\hat{\mathbf{A}}$ , and means for generating an output of the expected value for the estimation error of associated lines of correlation and for providing the output to a user via the output, whereby a CR bound may be developed for determining the performance of an estimate of a mixing matrix  $\hat{\mathbf{A}}$  developed in the blind separation of an overcomplete set of mixed signals in order that a user may know the performance limitations of a blind separation apparatus,

15

20

25

wherein the means for determining the expected value for the estimation error

determines an estimation error by calculating  $E\{\theta_i - \hat{\theta}_i\}^2$  where

$$E\{\theta_i - \hat{\theta}_i\}^2 \geq \frac{\lambda_k^2}{2N\mathbf{u}^T(\theta_i)\mathbf{p}^T\mathbf{R}_{w(v)}^{-1}\mathbf{p}\mathbf{u}(\theta_i)}, \text{ where:}$$

$E\{\theta_i - \hat{\theta}_i\}^2$  is an expected value for the estimation error of associated

lines of correlation;

30

5  $\theta_i = \arctan\left(\frac{\mathbf{a}_i}{\|\mathbf{a}_i\|}\right), \text{ where } \mathbf{a}_i = \begin{bmatrix} a_{1i} \\ a_{2i} \end{bmatrix}, i = 1, 2, \dots, M, \text{ and } \hat{\mathbf{A}} = \hat{\mathbf{A}}(\theta) = \mathbf{u}(\theta_i);$

$\hat{\theta}_i$  is an estimated value corresponding to an actual value of  $\theta_i$ ;

$\lambda_k^2$  is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A}(\theta))$  used for the estimation of the mixing matrix  $\hat{\mathbf{A}}$  and the estimation of a source signal estimate matrix  $\hat{\mathbf{S}}$ ;

10  $N$  is a number of data samples used in the generation of the mixing matrix  $\hat{\mathbf{A}}$  and the source signal estimate matrix  $\hat{\mathbf{S}}$ ;

$$\mathbf{u}(\theta_i) = \begin{bmatrix} \cos(\theta_i) \\ \sin(\theta_i) \end{bmatrix};$$

$$\mathbf{P} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix};$$

$T$  is the transpose operator; and

15  $\mathbf{R}_{\mathbf{W}(\mathbf{V})}^{-1} = \begin{bmatrix} \sigma_{\mathbf{W}(\mathbf{V})}^2 & \rho\sigma_{\mathbf{W}(\mathbf{V})}^2 \\ \rho\sigma_{\mathbf{W}(\mathbf{V})}^2 & \sigma_{\mathbf{W}(\mathbf{V})}^2 \end{bmatrix}, \text{ where } \sigma_{\mathbf{W}(\mathbf{V})}^2 \text{ is a cross correlation of a noise set and } \rho \text{ is a constant multiplier value.}$

44. (Cancelled).

20 45. (Currently Amended) ~~A computer program product for determining a CR bound for a source signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of mixed signals as set forth in claim 44, A computer program product for~~  
determining a CR bound for an source signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an overcomplete set of mixed signals, the computer program  
25 product being written onto a medium readable on a data processing system including a processor, a memory coupled with the processor, an input coupled with the processor, an output coupled with the processor, with the computer program product comprising means for generating a CR bound for the source signal estimate matrix  $\hat{\mathbf{S}}$ .

5        and means for generating an output of the expected value for the estimation error of  
associated lines of correlation and for providing the output to a user via the output,  
whereby a CR bound may be developed for determining the performance of an  
estimate of a source signal estimate matrix  $\hat{\mathbf{S}}$  developed in the blind separation of an  
overcomplete set of mixed signals in order that a user may know the performance  
10       limitations of a blind separation apparatus,

wherein the means for determining the expected value for the estimation error

determines an estimation error by calculating  $E\{\|\mathbf{W}(\mathbf{S}) - \mathbf{W}(\hat{\mathbf{S}})\|^2\}$

where  $E\{\|\mathbf{W}(\mathbf{S}) - \mathbf{W}(\hat{\mathbf{S}})\|^2\} \geq \left( \sigma_v^2 \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \hat{\mathbf{A}}^T(\theta) \hat{\mathbf{A}}(\theta) + \lambda^2 \mathbf{I} \right)^{-1}$ , where

$\sigma_v^2$  represents a noise level;

15        $\rho$  is a constant multiplier value;

$\hat{\mathbf{A}}$  is an estimated mixing matrix;

$\theta_i = \arctan\left(\frac{\mathbf{a}_i}{\|\mathbf{a}_i\|}\right)$ , where  $\mathbf{a}_i = \begin{bmatrix} a_{1i} \\ a_{2i} \end{bmatrix}$ ,  $i = 1, 2, \dots, M$ , and  $\hat{\mathbf{A}} = \hat{\mathbf{A}}(\theta) = \mathbf{u}(\theta_i)$ ;

$\lambda_k^2$  is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A}(\theta))$ ; and

$\mathbf{I}$  is an identity matrix.

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46. (New) An apparatus for blind separation of an overcomplete set of mixed signals as set forth in claim 5, wherein the means for generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:

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- i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the frequency domain using a Fourier operator;
- ii. means for using a mutual information criterion to determine a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;

5                   iii. means for determining a random variable  $ang = \arctan \frac{x_i(band)}{x_j(band)}$ ,

where  $x_i(band)$  and  $x_j(band)$  represent Fourier values of mixture in the selected frequency band, and an optimal threshold ANG for  $ang$ , where the optimal threshold ANG is determined by computing the entropy  $E(ang, ANG)$  vs. ANG and searching for the optimal value of ANG corresponding to the minimum rate of descent of the entropy  $E(ang, ANG)$ ;

iv. means for recalculating  $ang$  based on the optimal threshold ANG;

v. means for using a standard peak detection technique to determine the number and values of local maxima of a histogram of  $ang$  where the local maxima represent angles which are inserted into the estimated mixing matrix  $\hat{\mathbf{A}}$  to provide an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ .

47. (New) An apparatus for blind separation of an overcomplete set of mixed signals as set forth in claim 46, wherein the means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:

i. means for clustering the mixed signal samples in the Fourier domain along the lines of correlation with one cluster per source using a straight distance metric geometric constraint, with the clusters representing estimates of the Fourier domain representation of  $\hat{\mathbf{S}}$ ,  $\mathbf{F}(\hat{\mathbf{S}})$ , where  $\mathbf{F}$  represents a Fourier domain operator ; and

ii. means for evaluating a convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , developed from the log likelihood function  $L(\mathbf{F}(\hat{\mathbf{S}}) | \mathbf{F}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source signals in the

5           Fourier domain following the probability  $P(\mathbf{F}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|}$ , where  
  
 $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ ,  
evaluated based on the clustered mixed signal samples to determine whether the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, and if the convergence criteria,  $\min$   
 $\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is not met, iteratively adjusting the clustering of the mixed signal  
10           samples and parameters of the geometric constraint to create a new set of  
clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, to provide a final  
estimated mixing matrix  $\hat{\mathbf{A}}$ .

48. (New) An apparatus for blind separation of an overcomplete set of mixed signals as  
15           set forth in claim 47, wherein the means for jointly optimizing the source signal  
estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to  
generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing  
matrix  $\hat{\mathbf{A}}$  further comprises:  
  
i. means for obtaining a multi-band sparse domain estimate of the source signal  
20           estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ , applied in the Wavelet  
domain; and  
  
ii. means for using the adjusted geometric constraint corresponding to the final  
estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the Wavelet domain for the  
source signal estimate matrix  $\hat{\mathbf{S}}$ ,  $\mathbf{W}(\hat{\mathbf{S}})$ , and determining whether a  
25           convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$  is met for the source signal estimate  
matrix  $\hat{\mathbf{S}}$ , where the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is developed from  
the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A})$  with the assumption of  
Laplancity of source signals in the Wavelet domain following the probability

5             $P(W(S)) = \frac{\lambda}{2} e^{-\lambda c^T |W(\hat{S})|}$ , where  $c^T = [1, 1, \dots, 1]$  is a unit vector, and if the  
  
convergence criteria is not met,  $\min \lambda c^T |W(\hat{S})|$ , iteratively adjusting the  
  
clustering of the mixed signal samples to create a new set of clusters until the  
  
convergence criteria,  $\min \lambda c^T |W(\hat{S})|$ , is met, to provide a final source signal  
  
estimate matrix  $\hat{S}$ .

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49. (New) An apparatus for blind separation of an overcomplete set of mixed signals as  
set forth in claim 48, wherein the apparatus is configured for separating mixed  
acoustic signals.

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50. (New) An apparatus for blind separation of an overcomplete set of mixed signals as  
set forth in claim 48, wherein the apparatus is configured for separating mixed radio  
frequency signals.

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51. (New) A method for blind separation of an overcomplete set of mixed signals as set  
forth in claim 16, wherein the step of generating an initial estimate of the estimated  
mixing matrix  $\hat{A}$  comprises the sub steps of:

25

- i. transforming the mixed signal matrix  $X$  into the frequency domain  
using a Fourier operator;
- ii. using a mutual information criterion to determine a frequency band  
within the sparse domain that contains the most information that can  
be used to determine lines of correlation to determine the number of  
signal sources;

30

- iii. determining a random variable  $ang = \arctan \frac{x_i(band)}{x_j(band)}$ , where  $x_i(band)$   
and  $x_j(band)$  represent Fourier values of mixture in the selected  
frequency band, and an optimal threshold  $ANG$  for  $ang$ , where the  
optimal threshold  $ANG$  is determined by computing the entropy



- 5 E(*ang*, ANG) vs. ANG and searching for the optimal value of ANG corresponding to the minimum rate of descent of the entropy E(*ang*, ANG);
- iv. recalculating *ang* based on the optimal threshold ANG;
- v. using a standard peak detection technique to determine the number and  
10 values of local maxima of a histogram of *ang* where the local maxima represent angles which are inserted into the estimated mixing matrix  $\hat{\mathbf{A}}$  to provide an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$ .

52. (New) A method for blind separation of an overcomplete set of mixed signals as set  
15 forth in claim 51, wherein the step of jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$  comprises the sub steps of:

- i. clustering the mixed signal samples in the Fourier domain along the lines of  
20 correlation with one cluster per source using a straight distance metric geometric constraint, with the clusters representing estimates of the Fourier domain representation of  $\hat{\mathbf{S}}$ ,  $\mathbf{F}(\hat{\mathbf{S}})$ , where  $\mathbf{F}$  represents a Fourier domain operator ; and
- ii. evaluating a convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , with the convergence criteria,  
25  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , developed from the log likelihood function  $\mathbf{L}(\mathbf{F}(\hat{\mathbf{S}}) | \mathbf{F}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source signals in the Fourier domain following the probability  $\mathbf{P}(\mathbf{F}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|}$ , where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit  
vector, with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , evaluated based on the clustered mixed signal samples to determine whether the convergence criteria,  
30  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, and if the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is not met, iteratively adjusting the clustering of the mixed signal samples and

5 parameters of the geometric constraint to create a new set of clusters until the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, to provide a final estimated mixing  
matrix  $\hat{\mathbf{A}}$ .

53. (New) A method for blind separation of an overcomplete set of mixed signals as set  
10 forth in claim 52, wherein the wherein the step of jointly optimizing the source signal  
estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to  
generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing  
matrix  $\hat{\mathbf{A}}$  further comprises the sub steps of:

- i. obtaining a multi-band sparse domain estimate of the source signal estimate  
15 matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ , applied in the Wavelet domain;  
and
- ii. using the adjusted geometric constraint corresponding to the final estimated  
mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the Wavelet domain for the source  
signal estimate matrix  $\hat{\mathbf{S}}$ ,  $\mathbf{W}(\hat{\mathbf{S}})$ , and determining whether a convergence  
20 criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$  is met for the source signal estimate matrix  $\hat{\mathbf{S}}$ , where  
the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is developed from the log likelihood  
function  $\mathbf{L}(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source  
signals in the Wavelet domain following the probability  $\mathbf{P}(\mathbf{W}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|}$ ,  
where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, and if the convergence criteria is not met,  
25  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , iteratively adjusting the clustering of the mixed signal samples  
to create a new set of clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is  
met, to provide a final source signal estimate matrix  $\hat{\mathbf{S}}$ .

- 5 54. (New) A method for blind separation of an overcomplete set of mixed signals as set forth in claim 53, wherein the method is configured to separate mixed acoustic signals.
- 10 55. (New) A method for blind separation of an overcomplete set of mixed signals as set forth in claim 53, wherein the method is configured to separate mixed radio frequency signals.
- 15 56. (New) A computer program product for blind separation of an overcomplete set of mixed signals as set forth in claim 27, wherein the means for generating an initial estimate of the estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:
- i. means for transforming the mixed signal matrix  $\mathbf{X}$  into the frequency domain using a Fourier operator;
  - ii. means for using a mutual information criterion to determine a frequency band within the sparse domain that contains the most information that can be used to determine lines of correlation to determine the number of signal sources;
  - 20 iii. means for determining a random variable  $ang = \arctan \frac{x_i(band)}{x_j(band)}$ ,  
where  $x_i(band)$  and  $x_j(band)$  represent Fourier values of mixture in the selected frequency band, and an optimal threshold ANG for  $ang$ ,  
25 where the optimal threshold ANG is determined by computing the entropy  $E(ang, ANG)$  vs. ANG and searching for the optimal value of ANG corresponding to the minimum rate of descent of the entropy  $E(ang, ANG)$ ;
  - iv. means for recalculating  $ang$  based on the optimal threshold ANG;
  - 30 v. means for using a standard peak detection technique to determine the number and values of local maxima of a histogram of  $ang$  where the local maxima represent angles which are inserted into the estimated

5                                    mixing matrix  $\hat{\mathbf{A}}$  to provide an initial estimate of the estimated mixing  
matrix  $\hat{\mathbf{A}}$ .

57. (New) A computer program product for blind separation of an overcomplete set of  
mixed signals as set forth in claim 56, wherein the means for jointly optimizing the  
10                                    source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative  
manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final  
estimated mixing matrix  $\hat{\mathbf{A}}$  comprises:

- i. means for clustering the mixed signal samples in the Fourier domain along the  
lines of correlation with one cluster per source using a straight distance metric  
15                                    geometric constraint, with the clusters representing estimates of the Fourier  
domain representation of  $\hat{\mathbf{S}}$ ,  $\mathbf{F}(\hat{\mathbf{S}})$ , where  $\mathbf{F}$  represents a Fourier domain  
operator ; and
- ii. means for evaluating a convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , with the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , developed from the log likelihood function  
20                                     $\mathbf{L}(\mathbf{F}(\hat{\mathbf{S}}) | \mathbf{F}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source signals in the  
Fourier domain following the probability  $\mathbf{P}(\mathbf{F}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|}$ , where  
 $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, with the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ ,  
evaluated based on the clustered mixed signal samples to determine whether the  
convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, and if the convergence criteria,  $\min$   
25                                     $\lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is not met, iteratively adjusting the clustering of the mixed signal  
samples and parameters of the geometric constraint to create a new set of  
clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{F}(\hat{\mathbf{S}})|$ , is met, to provide a final  
estimated mixing matrix  $\hat{\mathbf{A}}$ .

5 58. (New) A computer program product for blind separation of an overcomplete set of mixed signals as set forth in claim 57, wherein the wherein the means for jointly optimizing the source signal estimate matrix  $\hat{\mathbf{S}}$  and the estimated mixing matrix  $\hat{\mathbf{A}}$  in an iterative manner, to generate an optimized source signal estimate matrix  $\hat{\mathbf{S}}$  and a final estimated mixing matrix  $\hat{\mathbf{A}}$  further comprises:

- 10 i. means for obtaining a multi-band sparse domain estimate of the source signal estimate matrix  $\hat{\mathbf{S}}$  using the relationship  $\mathbf{X} = \hat{\mathbf{A}}\hat{\mathbf{S}} + \mathbf{V}$ , applied in the Wavelet domain; and
- 15 ii. means for using the adjusted geometric constraint corresponding to the final estimated mixing matrix  $\hat{\mathbf{A}}$  in each of the bands of the Wavelet domain for the source signal estimate matrix  $\hat{\mathbf{S}}$ ,  $\mathbf{W}(\hat{\mathbf{S}})$ , and determining whether a convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$  is met for the source signal estimate matrix  $\hat{\mathbf{S}}$ , where the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is developed from the log likelihood function  $L(\mathbf{W}(\hat{\mathbf{S}}) | \mathbf{W}(\mathbf{X}), \mathbf{A})$  with the assumption of Laplanicity of source signals in the Wavelet domain following the probability
- 20  $\mathbf{P}(\mathbf{W}(\mathbf{S})) = \frac{\lambda}{2} e^{-\lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|}$ , where  $\mathbf{c}^T = [1, 1, \dots, 1]$  is a unit vector, and if the convergence criteria is not met,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , iteratively adjusting the clustering of the mixed signal samples to create a new set of clusters until the convergence criteria,  $\min \lambda \mathbf{c}^T |\mathbf{W}(\hat{\mathbf{S}})|$ , is met, to provide a final source signal estimate matrix  $\hat{\mathbf{S}}$ .

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59. (New) A computer program product for blind separation of an overcomplete set of mixed signals as set forth in claim 57, wherein the computer program product is configured for separating mixed acoustic signals.

- 5     60. (New) A computer program product for blind separation of an overcomplete set of  
mixed signals as set forth in claim 57, wherein the computer program product is  
configured for separating mixed radio frequency signals

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